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STUDIES OF DISPLAY SYMBOL LEGIBILITY

Part VI. Leroy and Courtney Symbols

MAY 1966

D. Shurtleff
D. Owen

Prepared for
DEPUTY FOR ENGINEERING AND TECHNOLOGY
DECISION SCIENCES LABORATORY
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

Project 7030
Prepared by
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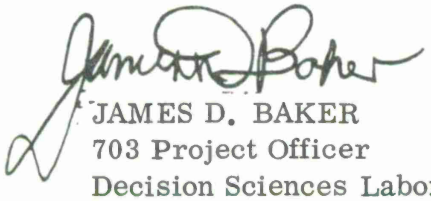
FOREWORD

This report is one of a series describing symbol legibility for television display. Additional information on this topic may be found in the following reports: "Studies of Display Symbol Legibility: The Effects of Line Construction, Exposure Time, and Stroke Width," by B. Botha and D. Shurtleff, The MITRE Corp., Bedford, Mass., ESD-TR-63-249, February 1963; "Studies of Display Symbol Legibility, II: The Effects of the Ratio of Width of Inactive to Active Elements Within a TV Scan Line and the Scan Pattern Used in Symbol Construction," by B. Botha and D. Shurtleff, The MITRE Corp., Bedford, Mass., ESD-TR-63-440, July 1963; "Studies of Display Symbol Legibility, III: Line Scan Orientation Effects," by B. Botha, D. Shurtleff, and M. Young, The MITRE Corp., Bedford, Mass., ESD-TR-65-138, May 1966; "Studies of Display Symbol Legibility, IV: The Effects of Brightness, Letter Spacing, Symbol Background Relation and Surround Brightness on the Legibility of Capital Letters," by D. Shurtleff, B. Botha, and M. Young, The MITRE Corp., Bedford, Mass., ESD-TR-65-134, May 1966; and "Studies of Display Symbol Legibility, V: The Effects of Television Transmission on the Legibility of Common, Five-Letter Words," by G. Kosmider, The MITRE Corp., Bedford, Mass., ESD-TR-65-135, May 1966.

REVIEW AND APPROVAL

This Technical Report has been reviewed and is approved.



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ABSTRACT

At vertical resolutions of 12- , 10- , 8- , and 6-scan lines per symbol height, the legibility of Courtney alphanumeric symbols, designed especially for television, was compared with that of standard Leroy symbols. These symbols were presented singly on a 525-line TV monitor, and the speed and accuracy with which they were identified by groups of subjects having normal vision were recorded. A group of subjects viewed only the Courtney symbols, while another viewed only the Leroy. The results showed that, at any resolution value, identification of Courtney symbols was no better than for Leroy. Some practice was required with the Courtney symbols before it was possible to obtain a performance equal to that of the Leroy. This study supports the findings of other experiments: that a resolution of 10 lines per symbol height remains the lowest value recommended for TV displays.

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SECTION I

INTRODUCTION

IMPORTANCE OF SYMBOLS

Television is a valuable display device for systems use because of its versatility, ease of signal transmission, reliability of image reproduction, ease of maintenance, and comparatively low cost. In addition, the ability of television to combine different data inputs into a single composite display is well known. Nevertheless, the acceptability of television for many military and industrial systems applications depends upon its ability to display symbols which can be accurately and quickly identified by the viewer.

Need for a Legibility Evaluation

This ability has seldom been determined through objective performance tests that provide estimates of accuracy and speed (legibility) of symbol identification. Even though television is widely used for entertainment, education, and communication, the research which might have solved some of the legibility problems has been directed elsewhere instead. Commercial TV studies lean to such problems as picture quality,[1] flicker,[2] color quality,[3,4] and in educational TV, to evaluations of television as an instructional device.[5,6] When television is used as a means of communication in system settings, symbol legibility is often determined by subjective opinions, preferences, or even guesses.

OBJECTIVES OF STUDY

In an effort to provide some quantitative data on the legibility of TV displayed symbols, a series of experiments was begun which simulated

some of the parameters of television.[7,8,9] These simulated TV studies were followed by another study, in which live closed-circuit television was used.[10] The present study, which also was made with live television, has two major purposes: (a) to study the legibility of capital letters and numerals with vertical resolutions of 12, 10, 8, and 6 active lines per symbol height, and (b) to determine the relative legibilities of two lettering fonts, one of which was designed specially for use on television.

Relation of Resolution to Legibility

These simulated TV studies all showed that the accuracy and speed of identification is nearly the same for symbols with 10 horizontal lines per symbol height as it is for symbols with solid strokes. Performance at 5 lines was worse than the performance at either 10 lines or solid strokes. These data indicated a need for additional investigations of resolutions lying between 10 and 5 lines per symbol height. Also desirable was a comparison of the performance with simulated television to that with live television, in order to determine their correspondence.

Evaluation of the Courtney Symbols

A second purpose of this study was to evaluate a specially designed set of alphanumerics whose originator, the Courtney Company, felt would improve the legibility of television displays in the "Spanrad" system.[11] Their decision to design a new set of symbols came about after a series of ratings and opinions by several of their observers had indicated that none of the existing printing styles satisfied TV display requirements. They attempted to evaluate the relative legibility of the new symbols by comparing them with Menu style letters and numerals, and also, with a set of alphanumerics made up of Memphis Bold letters and Spartan Bold Italic numerals.

The last two sets of alphanumerics were, in their opinion, the best of the commercially available styles.

Courtney's Evaluation Methods

The procedure used for the final evaluation of individual symbols making up the three sets rests upon agreement among several observers (judges) about symbol legibility. This is typical of the procedure used throughout their study. Their description of the evaluation procedure, which they followed, is quoted below:

> ...side-by-side comparisons were made. A character was selected only if there was unanimous consent of the judges. This was almost invariably easy to reach. In certain cases, as for example, 'I,' 'J,' and 'L,' there is so little difference between them that any variety would be acceptable. On the whole, however, the especially devised style was superior so the decision was made to adopt it in its entirety.

Need for Objective Evaluation Methods

Since the evaluation procedures used by the Courtney Company were based upon subjective judgments, it was necessary to investigate the legibility of the Courtney symbols by using more objective measures. The use of other measures is particularly desirable since Tinker[12] has shown that subjective judgments of legibility do not, in most cases, have a high correlation with objective measures of legibility.

Courtney and Leroy Fonts Compared

In addition, a better determination of the value of the new symbols, as a lettering font for general television applications, could be made if it were compared with an alternative font that was commercially available. Leroy alphanumerics were chosen for this purpose. A comparison of these two fonts, at the various values of resolution, should indicate any conditions to

which application of the new lettering font would prove advantageous. If no distinct advantage were found for the new font, then the standard lettering font would seem preferable for general display use because of its availability, familiarity, and ease of construction.

SECTION II
METHODS AND PROCEDURES

SELECTION OF SUBJECTS

Eight subjects between the ages of 22 and 45, who were screened for visual acuity and color vision on the Bausch and Lomb Ortho-Rater, were employed.

Matching the Groups

Because the two groups of subjects might differ initially in their ability to identify symbols in the two fonts, an attempt was made to match the groups in speed and accuracy of symbol identification before the start of the experiment. Therefore, all the subjects identified symbols of solid stroke in both fonts, and the speed and accuracy of identification were recorded. The groups were closely matched, on the basis of the scores with the solid stroke symbols.

How Groups Became Mismatched

Because of difficulty with the apparatus, several subjects in one group had to be replaced after the experiment had begun. As a consequence, the groups were no longer so closely matched: the group identifying the Courtney symbols had average identification times slower than the Leroy group, and the variability among the subjects in the Courtney group was greater as well. It was decided, therefore, to repeat the entire experiment a second time in order to give the Courtney symbols an additional chance to show any special merit which might appear only after extensive familiarization with this new font. Also, one subject from each group was given some additional practice in the most difficult viewing condition (6 lines per symbol height) to determine if the new symbols were superior in an unfavorable viewing condition.

EXPERIMENTAL DESIGN

A mixed design was used in which four of the subjects identified symbols in the Courtney style, and another four identified symbols in the Leroy style. All eight subjects identified symbols having resolutions of 12, 10, 8, and 6 active television lines per symbol height. The order of presentation of the resolutions within a group was arranged such that each one preceded and followed all of the others an equal number of times. Also, all resolutions appeared an equal number of times in the first, second, third, and fourth position of the sequence.

Symbol Geometry, Construction and Display

The average symbol width for the two fonts was 3/4 of the symbol height. The stroke-width of the Courtney symbols was variable, with a ratio of stroke-width to height ranging from 1/4 to 1/6. The Leroy font had a ratio of stroke-width to height of 1/6. Both sets of alphanumerics are shown in Figure 1. It was necessary to modify the standard Leroy "zero" and "I" in order to differentiate the "zero" from the letter "O", and the numeral "one" from the letter "I."

The symbols were photographed on 35-mm film strips each containing 180 symbols of a given font with the 36 symbols appearing 5 times each. The sequence of symbols on the film strip was determined by a table of random numbers. Details of the apparatus and the experimental situation have been described in a previous paper.[10]

The symbols were projected onto a translucent screen which was mounted on a modified Motion Analyzer. The symbols were picked up on a standard 525-line Fairchild television camera (Model TC-100), and shown to the subject on a Miratel 14-inch portable video monitor. The camera-

Figure 1. Leroy and Courtney Alphanumerics

to-screen distance was arranged to obtain the desired line resolution, and the subject-to-monitor distance was arranged to maintain a subtended angle of 11 minutes of arc. Each of the subjects made 180 symbol identifications (5 per symbol) for each of the four values of resolution. The same number and type of identifications were repeated in the replication of the experiment. A stepping switch controlled the advance of the film through the projector and provided a number of different symbol sequences which helped to prevent the subjects memorizing the letter sequences.

The active lines in the symbols had an average brightness of approximately 20 foot-lamberts; the background brightness was approximately 1.5 foot-lamberts. It was not possible to maintain a constant value of brightness due to inherent variability in the television system. Symbol brightness was set to 20 foot-lamberts before each experimental session, but measurements following each session showed that brightness could have decreased to as little as 15 foot-lamberts, or increased to as much as 30 foot-lamberts, during the session. Also, the light intensity was not distributed uniformly throughout a symbol. After much trial and error, it was found that the most suitable procedure was to make fine brightness adjustments by use of the beam control on the television camera, rather than by use of the brightness and contrast controls on the monitor. When the beam control was used, non-uniformity of brightness throughout the symbol was minimized, and brightness readings before and after each experimental session showed less variability than when the monitor controls were used. Additional adjustments of the television equipment, e.g., target, electrical focusing, and optical focusing, were always made by the same individual before each experimental session. These adjustments were made with the same arbitrarily selected standard symbol displayed, in order to maintain better uniformity of symbol appearance.

Duties and Responses of Subjects

The subject initiated the exposure of a symbol by depressing a button. The exposure was ended when the subject made his verbal identification. The subject was instructed to make his identifications as quickly and accurately as possible. Two properties of the subject's response were recorded: the time required to identify each symbol and the symbol named.

SECTION III

RESULTS FOR THE FIRST PART OF THE EXPERIMENT

AVERAGE IDENTIFICATION TIMES

The results obtained for the first part of the experiment are shown in Figures 2 and 3 and Tables I and II. Figure 2 and Table I indicate that the average time required to identify symbols in both fonts increases regularly with each decrease in the number of lines (resolutions) per symbol height. Also, the average identification time was consistently slower for the Courtney symbols than for the Leroy symbols. It will be seen later, when the results for the second part are presented, that part of the differences between the two fonts for the various resolutions was probably due to unfamiliarity with the Courtney symbols.

Statistical Analysis

For statistical analysis, the average time scores were converted to reciprocals in order to normalize the distribution of raw scores and to eliminate the correlation between means and variances (Table I). An analysis of covariance of the transformed scores took account of initial group differences in ability to identify symbols in the two fonts. The results of the analysis indicated that only resolution was a statistically significant source of variance. The differences between fonts were not statistically significant, nor was there a significant interaction between fonts and resolution.

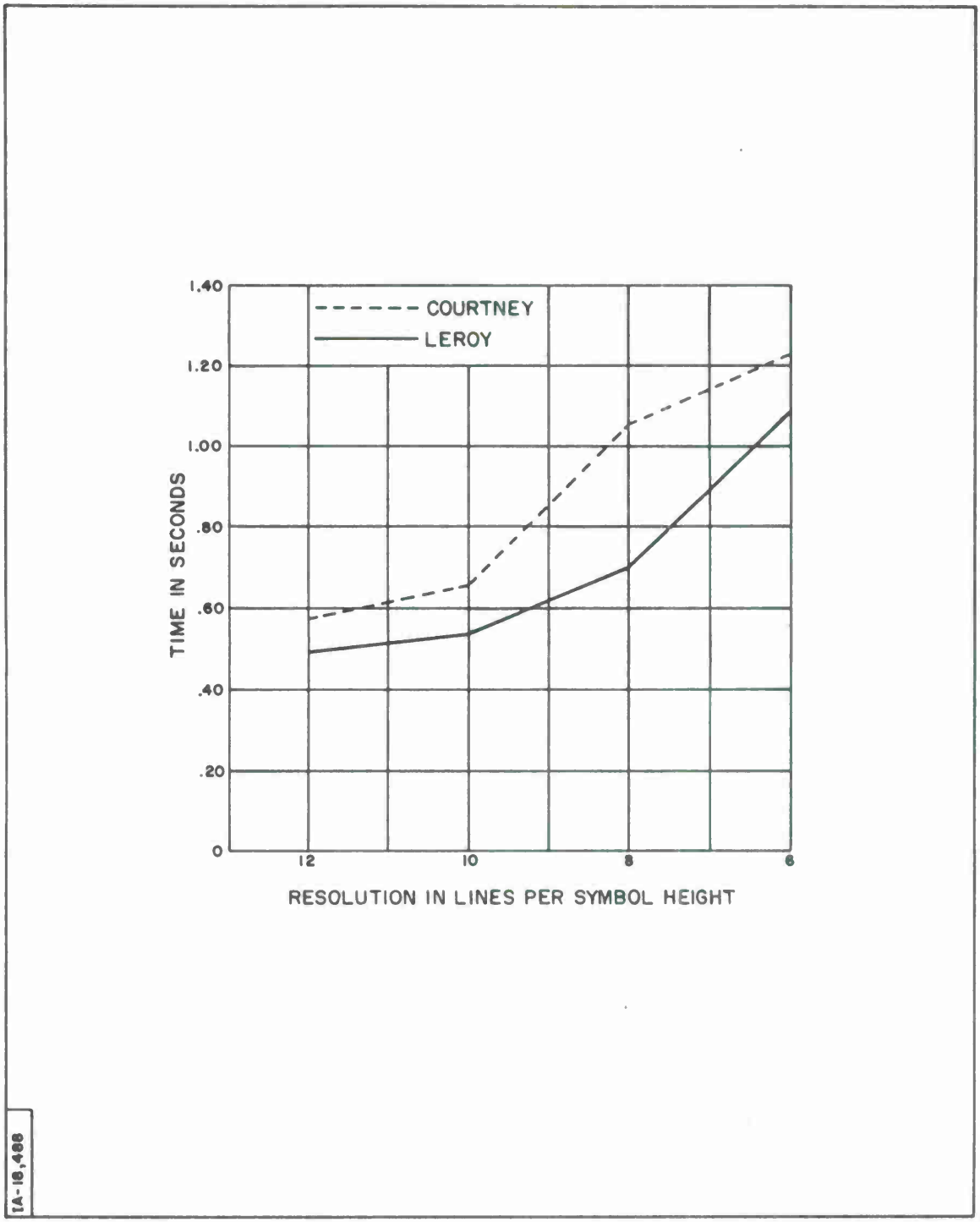

Figure 2. Average Identification Times versus Resolution

Table I

Average Identification Times and Standard Deviations

		Active Scan Lines per Symbol Height			
		6	8	10	12
Courtney	$\bar{X}$	1.22	1.06	0.66	0.57
	σ	0.27	0.69	0.17	0.09
Leroy	$\bar{X}$	1.08	0.70	0.54	0.49
	σ	0.29	0.16	0.04	0.04

Resolution Pairs

In order to determine differences between successive pairs of resolutions, a series of "t" tests were performed. Significant differences were found between 12 and 10, 10 and 8, and 8 and 6 lines per symbol height.

PERCENTAGE OF ERRORS

Figure 3 and Table II show the percentage of errors for the various resolutions and fonts. The percentage of errors was similar for the two fonts, but a regular increase in error occurred for each decrease in the number of lines per symbol height. The standard deviation of error scores, shown in Table II, was much larger for the Courtney symbols than for the Leroy symbols, which was probably due to different proficiencies among the subjects in learning the new symbols.

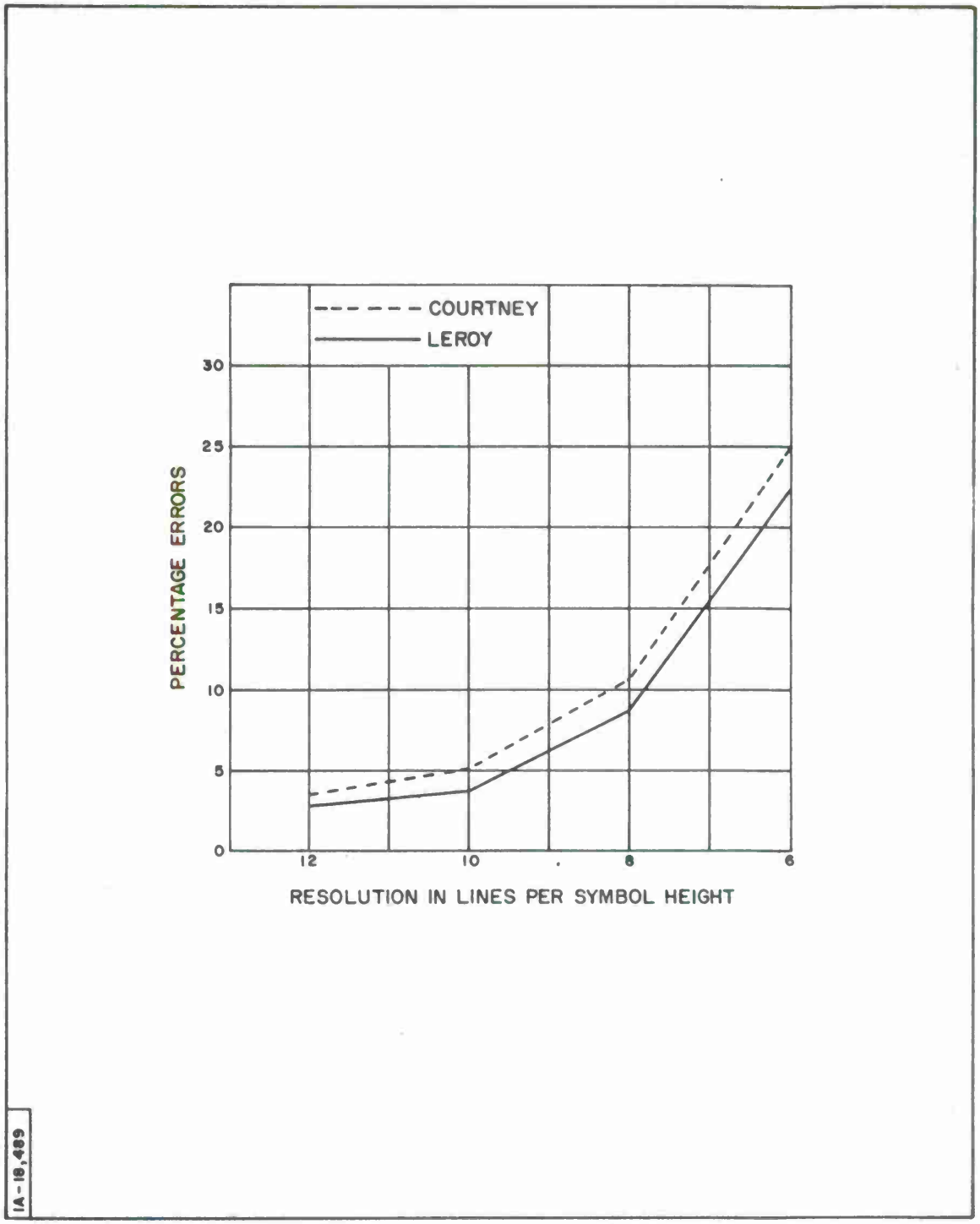

Figure 3. Percentage Errors

Table II

Average Percentage Errors and Standard Deviations

		Active Scan Lines per Symbol Height			
		6	8	10	12
Courtney	$\bar{X}$	25.2	10.7	5.2	3.4
	σ	10.0	10.6	4.1	1.5
Leroy	$\bar{X}$	22.5	8.6	3.5	2.8
	σ	0.6	3.1	2.0	0.8

Analysis of Variance

An analysis of variance* of the percentage of errors showed that the only significant source of variance was resolution. There were no significant differences between fonts, nor was there a significant interaction between resolution and font.

Resolution Pairs

The significance of the difference between percentage of errors for successive pairs of resolutions was determined by the Wilcoxon nonparametric test.[13] These tests indicated no significant differences between 12 and 10 lines per symbol height, but a significant difference between 10 and 8 and 8 and 6 lines per symbol height.

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* The results of the analysis of variance should be viewed with caution because of the truncated distribution of scores for the higher values of resolution.

SECTION IV

RESULTS FOR THE SECOND PART OF THE EXPERIMENT

AVERAGE IDENTIFICATION TIMES

Figure 4 and Table III show the average identification times obtained for the second part of the experiment. It is noted, (by comparing Figures 2 and 4) that performance is generally better than was the case in the first part, and identification times were more similar for symbols in the two fonts than they were in the first part. Also in the second part, the standard deviations of the time scores for the Courtney symbols were much lower than in the first part, and were closer to those found for the Leroy alphanumerics (see Table III).

Statistical Analysis

The average time scores were converted to reciprocals and submitted to an analysis of variance, which indicated the same results as for the first part, namely, that the only statistically significant source of variance was resolution. There were no significant differences between fonts, nor was the interaction between resolution and fonts significant.

Resolution Pairs

A series of "t" tests between means for successive pairs of resolution showed no significant differences between 12 and 10 lines per symbol height, but a significant difference between 10 and 8 and 8 and 6 lines per symbol height.

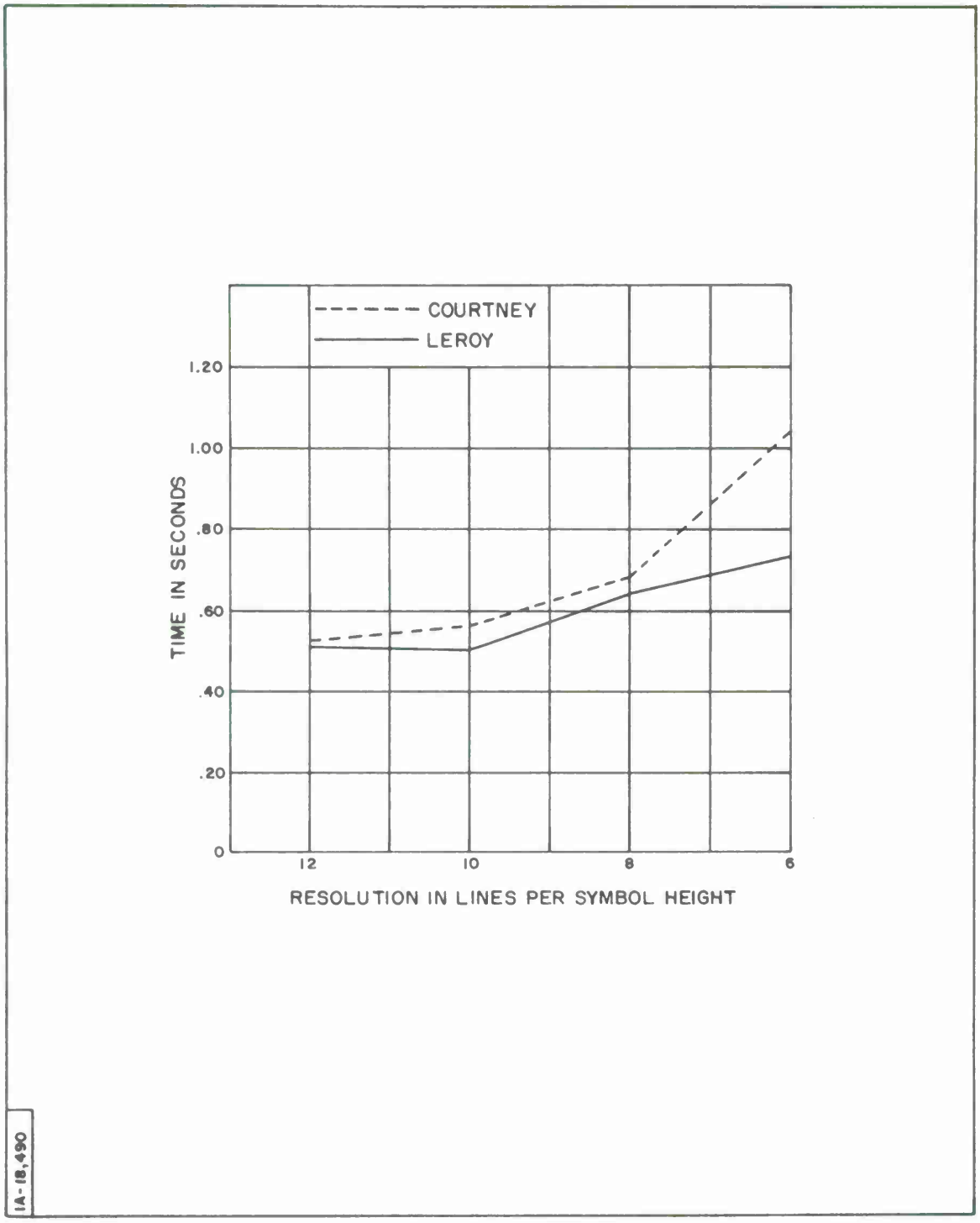

Figure 4. Average Identification Times versus Resolution

Table III

Average Identification Times

		Active Scan Lines per Symbol Height			
		6	8	10	12
Courtney	$\bar{X}$	1.04	0.69	0.56	0.53
	σ	0.28	0.16	0.08	0.06
Leroy	$\bar{X}$	0.74	0.65	0.50	0.51
	σ	0.17	0.14	0.04	0.05

PERCENTAGE OF ERRORS

In Figure 5 and Table IV, percentage of error scores are shown for the various line constructions and fonts obtained for the second part. A comparison of Figures 3 and 5 indicates a marked decrease in errors during the second part, particularly for 8 and 6 lines per symbol height. The reduction in errors at 6 and 8 lines is especially marked for the Courtney symbols.

Analysis of Variance

An analysis of variance of the percentage of errors* showed the same results as for the first part, namely, that the only significant source of variance occurred for resolution. There were no significant differences between fonts, nor was the interaction between fonts and resolution significant.

Resolution Pairs

A Wilcoxon nonparametric test of differences between means for successive pairs of resolution values indicated that only the difference between 8 and 6 lines per symbol height was statistically significant.

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* See footnote on page 14.

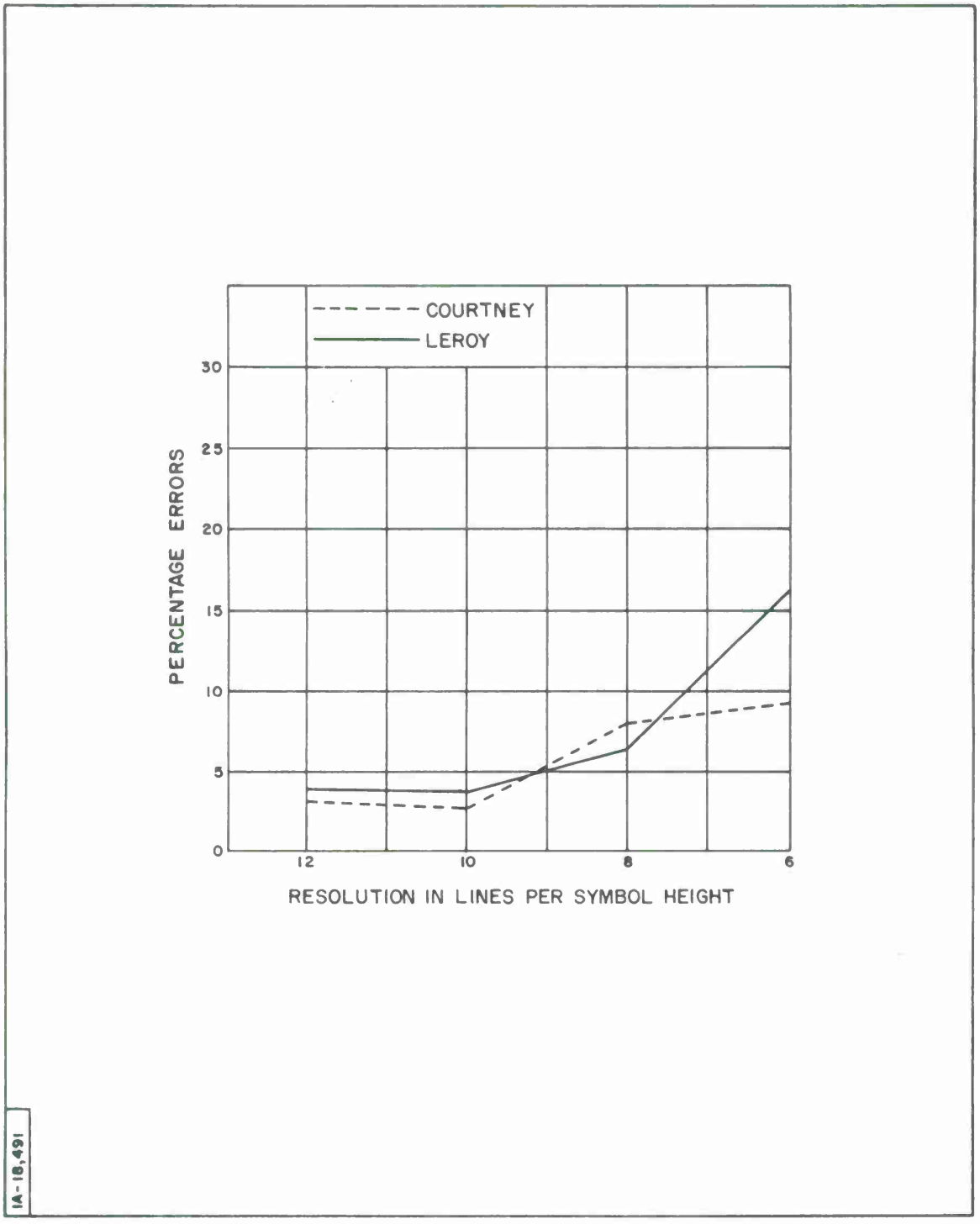

Figure 5. Percentage Errors

Table IV

Average Percentage Errors and Standard Deviations

		Active Scan Lines per Symbol Height			
		6	8	10	12
Courtney	$\bar{X}$	9.0	8.0	3.0	3.2
	σ	5.2	9.8	3.1	5.0
Leroy	$\bar{X}$	16.2	6.4	3.7	3.9
	σ	5.9	4.0	2.7	0.9

SECTION V

RESULTS FOR THE TWO SUBJECTS GIVEN ADDITIONAL PRACTICE

One subject from each group was given three additional experimental sessions with 6 lines per symbol height. The average times and errors for these sessions are shown in Table V. This table indicates that the major reduction in time and errors for both subjects occurred during the second part of the experiment, before the additional practice. Percentage of errors decreased a little during the additional sessions while the average time scores increased. The decrease in errors and increase in time probably reflect the subjects' concentration on accuracy at the cost of increasing identification times.

Table V

Average Identification Times and Percentage Errors

		6 Lines Part I	6 Lines Part II	Practice		
				1	2	3
Average Identification time	Courtney	1.18	0.70	0.85	0.74	0.77
	Leroy	1.38	0.65	0.72	1.05	1.11
Percentage Errors	Courtney	15.1	5.1	2.2	2.8	5.1
	Leroy	22.4	10.4	7.3	6.8	8.9

SECTION VI

INTERSYMBOL CONFUSION

Confusion matrices were constructed to show prominent sources of confusion between symbols. Those confusions which contributed 3.0 percent or more of the total number of errors made for each of the symbol fonts are presented in Tables VI and VII. A comparison of the total number of errors made for a given intersymbol confusion between the first and second part of the experiment indicates the extent to which the confusion was eliminated by practice. Table VI shows, for example, that in the first part "6" was called "4" twenty-one times, while in the second part "6" was called "4" only five times. On the other hand, it shows that there was little change in the confusion between "H" and "N" for the two parts of the experiment. In the first part, "H" was called "N" 17 times, and in the second, "H" was called "N" 18 times. In Table VII, which presents the major confusions for the Leroy symbols, the "H called M", the "C called G", and the "X called K" confusions were reduced by practice: they appear as prominent errors during the first part, but not during the second part. The remaining confusions shown in this table during the first part were not changed very much by practice and appear as major sources of error during the second part. In fact, the "S called 5" confusion increased from 3.0 percent of the total error in the first part to 9.5 percent of the total error during the second part.

Table VI

Courtney Symbol Confusions

Part I (Total Errors = 311)			Part II (Total Errors = 163)		
Symbol Confusions*	Number of Errors	Percentage of Errors	Symbol Confusions	Number of Errors	Percentage of Errors
6 called 4	21	6.8	H called N	18	11.0
H called N	17	5.5	U called W	12	7.4
U called W	17	5.5	9 called 7	12	7.4
S called 5	12	3.8	1 called I	11	6.7
1 called I	12	3.8	H called M	9	5.5
H called M	11	3.5	T called 7	6	3.7
I called 1	11	3.5	9 called P	6	3.7
9 called 7	11	3.5	R called 2	5	3.1
T called Y	10	3.2	V called Y	5	3.1
Z called I	10	3.2	5 called S	5	3.1
			6 called 4	5	3.1

* Confusions shown contributed 3 percent or more of the total number of errors made in the identification of the Courtney alphanumerics for Parts I and II of the experiment.

Table VII

Leroy Symbol Confusions

Part I (Total Errors = 264)			Part II (Total Errors = 211)		
Symbol Confusions*	Number of Errors	Percentage of Errors	Symbol Confusions	Number of Errors	Percentage of Errors
1 called I	24	9.1	B called 8	27	12.8
2 called Z	24	9.1	S called 5	20	9.5
B called 8	23	8.7	1 called I	16	7.6
H called M	12	4.5	2 called Z	15	7.1
G called 6	11	4.2	G called 6	13	6.2
C called G	8	3.0	H called N	10	4.7
S called 5	8	3.0	Q called O	9	4.3
X called K	8	3.0	7 called T	8	3.8

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* See footnote on page 22.

SECTION VII

DISCUSSION OF RESULTS

RELATIVE MERITS OF COURTNEY AND LEROY SYMBOLS

There seems little to be gained by using the Courtney symbols for television, since the performance was no better than that obtained with the Leroy alphanumerics. Furthermore, the data suggest that the viewer must be given practice with the Courtney symbols, before his performance becomes as good as that obtained without practice with a standard lettering font.

Symbol Orientations

An additional merit attributed to the Courtney symbols (by their designers) is their ease of identification when displayed in different orientations, e.g., sideways, upside-down, and so on. In the present study, the symbols were viewed in the usual orientation (upright) only. The possibility remains then that, when oriented other than upright, the new symbols might prove superior to the standard symbols.

Symbol Construction for TV

The reason why this might be so stems from the manner of symbol construction in television displays. In many conventional (non-TV) displays, a finding of symbol legibility for symbols displayed in one orientation would apply without reservation to symbols displayed in all other orientations, since the geometry of the symbol remains the same regardless of its orientation. In television, however, because of associated changes in the angle between symbol strokes and the scanning lines, changes in geometry occur when a symbol is placed in different orientations. For example, a symbol scanned by lines parallel to its base is geometrically different from the same symbol scanned by lines at an angle of 45 degrees to its base.

Conclusions from Display Results

Therefore, in the case of television, it might be argued that the new symbols possess some special merit which makes them less susceptible to changes resulting from different angles of scanning, even though no differences were found for the normal orientation used in the present study. However, there is some reason for believing that the present results might apply as well to symbols displayed in other orientations. A previous report[9] has shown that speed and accuracy of identification of symbols in a standard font were not altered significantly by simulated scan lines placed at different angles to the base of the symbols. For this one font, at least, the direction of scanning did not alter legibility, and the finding raises some doubt that the new font would demonstrate superior legibility under similar circumstances.

LEGIBILITY AND RESOLUTION

Conclusions about the amount of vertical resolution required for symbol legibility differ for the performance measures of this study. The data indicate that, if identification time is an important consideration, then resolutions of less than 10 lines per symbol height should be avoided. On the other hand, if only accuracy of identification is important, as few as eight lines per symbol height might be adequate, if the viewer is given some practice.

Variation in TV Equipment

For general television applications, these conclusions can apply only in a strictly logical sense to the particular television equipment used, because no two pieces of television equipment of the same type produce exactly the same symbols. For general application, the extent to which these conclusions

would have to be qualified could be determined by sampling a number of different cameras and monitors of the type used in the present study.

Effect of Resolution on Performance

Despite the logical limitations of the data, it is unlikely that the conclusions of this study would have been different. Even if other standard 525-line cameras and monitors had been used, all the results obtained to date (including both simulated and live studies[7, 9, 10] point to some deterioration of performance with resolutions of less than 10 lines per symbol height. Therefore, a general conclusion, based on both the results of this study and others,[7, 9, 10] is that resolutions of less than 10 lines per symbol height should be avoided. However, if a resolution of less than 10 lines per symbol height is required, then the amount of loss of legibility should be determined by use of performance tests such as those of this study and those proposed elsewhere.[14]

Effects of Display Surface

The results of the present study are limited further to symbols shown on the center part of the display surface. Greater resolution of from 12 to 15 lines per symbol height would be required for symbols displayed on the peripheral areas of the tube, where deflection defocusing would probably have a more adverse effect on legibility.

Determining Legibility Loss

Another approach that might be successfully employed to determine the amount of legibility loss for resolutions of less than 10 lines per symbol height is to identify and assess experimentally the effects on legibility of each of the many factors characteristic of live television. A step was taken in this direction in some previous studies, one of which investigated performance for simulated television constructions of 11 and 5 lines per symbol

height.[7] A comparison of the simulated with the live television showed, as one might expect, that the simulated constructions gave better performance, particularly for 5 or 6 lines per symbol height.

Symbol Part Deletions

This lack of agreement was anticipated, since the simulated studies showed the effect on performance of only one factor characteristic of live television constructions, namely, the deletions of selected parts of the symbol which occur as a consequence of the television scanning process.

Other Factors Affecting Legibility

Other factors characteristic of live television need to be identified, and their effects on legibility determined in the same way as was done for the factor mentioned above. Some of the more important factors are: video bandwidth, defocusing, and resolution characteristics of the phosphor. The separate effects of these factors, and others, could be determined by simulated studies while their combined effects on legibility could be checked by use of live television.

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13. ABSTRACT

At vertical resolutions of 12- , 10- , 8- , and 6-scan lines per symbol height, the legibility of Courtney alphanumeric symbols, designed especially for television, was compared with that of standard Leroy symbols. These symbols were presented singly on a 525-line TV monitor, and the speed and accuracy with which they were identified by groups of subjects having normal vision were recorded. A group of subjects viewed only the Courtney symbols, while another viewed only the Leroy. The results showed that, at any resolution value, identification of Courtney symbols was no better than for Leroy. Some practice was required with the Courtney symbols before it was possible to obtain a performance equal to that of the Leroy. This study supports the findings of other experiments: that a resolution of 10 lines per symbol height remains the lowest value recommended for TV displays.

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